Can Precision Farming Help Mitigate Climate Change?

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Can Precision Farming Help Mitigate Climate Change?

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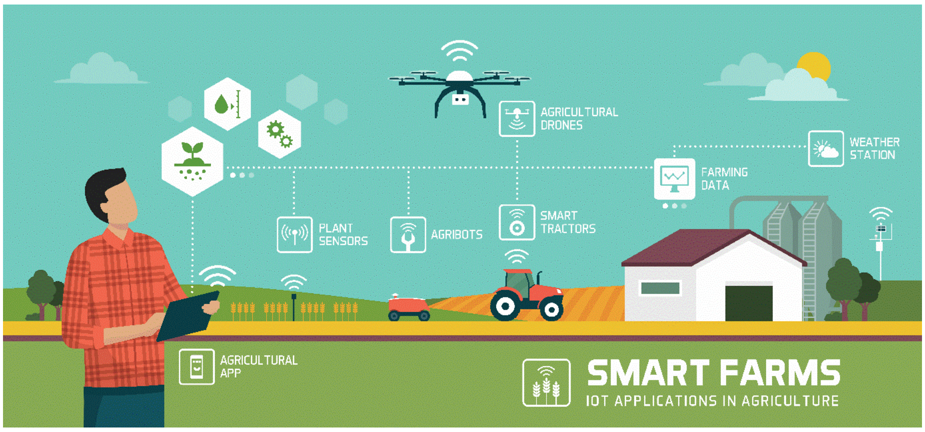
- Agriculture 4.0 or Precision farming is the current farming trend which uses technologies, to monitor and act, on individual farm assets in a targeted way
- Precision farming has the potential to reduce labour, free up farmers time, improve profits and benefit the environment if applied correctly
- Precision technologies positively benefit the environment in studies, however, benefits are often inferences only. In future, more specific research is required

What is precision farming?

Precision farming (PF) is a term used for the next big trend in the agriculture industry, often referred to as 'Agriculture 4.0'. This trend follows on from the 'Green Revolution'/'Third Agricultural Revolution' which occurred in the 1950s/60s. The 'Green Revolution' involved the intensification of farming systems through high yielding crops and animals (via increased genetic understanding), and the increased use and availability of large-scale mechanisation and irrigation. This advancement facilitated food production for a global population which had more than doubled, whilst only increasing land area cultivated by 30%. 'Agriculture 4.0', on the other hand, returns towards highly targeted individual asset level farming, in a less labour-intensive more efficient manner, through the integration of modern technologies. This targeted approach should allow individual animals and plants to be monitored constantly, improving productivity and reducing inputs over an entire farm system. Essentially PF facilitates doing the right thing, in the right place and at the right time.



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Definitions within PF, are constantly evolving alongside the technologies it seeks to utilise, however, there are two main sub-groups, these are precision agriculture (PA) and precision livestock farming (PLF). PA, despite its broad name, specifically focuses on the arable and horticultural crop aspects of farming and has seen far higher investment and research than its counterpart (Figure 1). PLF is specifically focused on livestock technologies, towards improving productivity, welfare and management practices. In recent years due to increased technological advancements, with regards cost-effectiveness, as well as financial incentives, PF technologies are increasingly abundant, with an estimated 75 million devices predicted to be collecting precision data worldwide by 2020.

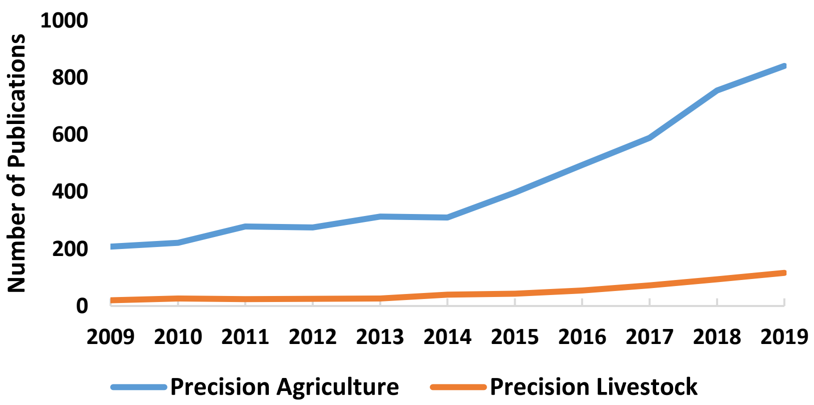


Figure 1. Publications over the last 10 years (Webofknowledge.com)

Broadly speaking there are 3 main components to PF technology applications, these are (1) Hardware and sensors (which are involved in acting upon or collecting data) (2) Data analysis and decision support systems (the software and/or cloud systems and machine learning algorithms which take data and process it into something meaningful) (3) Commodity and whole-farm focus (the process whereby decision support systems and models are made commercially and utilised across whole farms, and not just individual fields).

Alongside the economic benefits of PF, there is also increasing discussion with regards to their vital role in a sustainable agricultural future. Several studies note that PF enables equivalent or increased productivity/yields with a reduction in overall inputs (including fuel, feed, nutrients or water etc). As such, a reduction in greenhouse gas (GHG) emissions either directly or indirectly should be occurring. Whilst there is some direct evidence of emission reductions, limited direct GHG mitigation studies have been performed with regards to PF technologies to date.

Precision agriculture technologies and climate mitigation

PA technologies are related to crop growth and management, with several key technologies already in common use within this sector. Whilst, much discussion surrounding climate mitigation in agriculture is focused on animal-related methane emissions, recent reports from the UK government suggest that improved nutrient management in crops has a far higher potential for emission mitigation than livestock-related practices (Figure 2). This may be due to the main crop-related emission being nitrous oxide (N_2O) which has almost 10 times more impact on climate change per molecule than methane. Another area in which PA could play a mitigating role is through reducing future land conversion requirements by improving yields achieved within lands. One key technology which can be utilised to achieve these goals is variable rate application technologies (VRT).

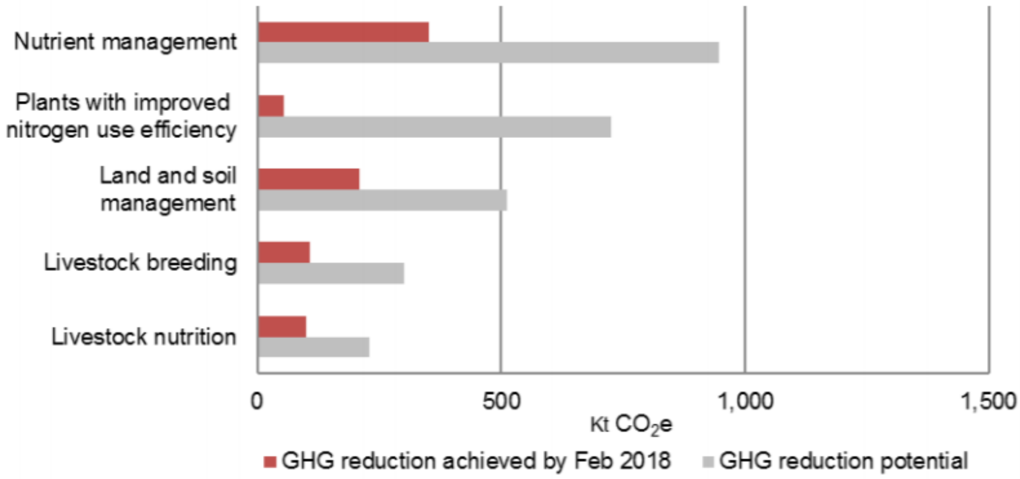


Figure 2. GHG reductions based on the uptake of key on-farm mitigation methods (GOV.UK)

Variable-rate technologies (VRT)

Variable-rate application involves applying inputs, including; seeds, slurry, pesticides, fertiliser and any other chemicals onto pastures/crops in precise and informed ways, rather than uniformly. Early research demonstrated that highly productive areas were influenced little by changes in nutrients applied, however, huge reductions in nitrogen application could be achieved on lower production areas whilst achieving similar yields and producing up to 34% less N_2O. VRT involves either map-based GPS systems and/or sensor-based systems. Both systems utilise field data to modulate inputs as required for the crop, and systems provide the most information for improved management when combined. VRTs have demonstrated high economic potential examples include;

- 8% increases in wheat yields for 10% reduced nitrogen utilised

- >2.5 times increase in €/ha over three years of VRT nitrogen application in corn
- Savings of 42 €/ha, 32 €/ha, 27 €/ha and 20 €/ha for maize, winter wheat, winter barley and sugar beet via variable herbicide application
- Yield increases of 6.45% over 4 years in winter wheat through variable-rate seeding
- 7% increase of net income on fields utilising variable rate seeding and data influenced management zones (this involves identifying low-performance fields and applying fewer seeds for example)

Alongside yield and profit gains one study suggested between a 5 – 10% GHG reductions via VRT. Data from 2018 as part of the UK 'Farm Practices Survey' demonstrated that uptake of VRT was only 21%. Based on the potential benefits of VRT, it is likely that improving uptake in the UK could lead to substantial reductions in direct and indirect GHG emissions. Further developments include the use of drones for VRT, whilst currently, this is against policies in the UK, drone spray-application could reduce fossil fuel consumption and have less negative effects on soil compaction than current machinery.

Machine guidance/autosteering

Machine guidance utilises global positioning systems (GPS) and global navigation satellite positioning systems (GNSS) to assist, or directly navigate vehicles. In row crop systems, machine guidance combines accurate field maps along with sensors (laser sensors and machine learning) to accurately navigate around crops. The main benefit of assisted steering (other than improved straight-line accuracy and efficient pathing) and full autonomy, is improved pass-to-pass efficiency, reducing overlap or gaps when performing tasks including applying fertiliser or tilling. Efficiency increases directly relate to savings in both fuel consumption and input applications. Due to the nature of these savings, machine guidance pairs synergistically with VRT. Studies of machine guidance have reported;

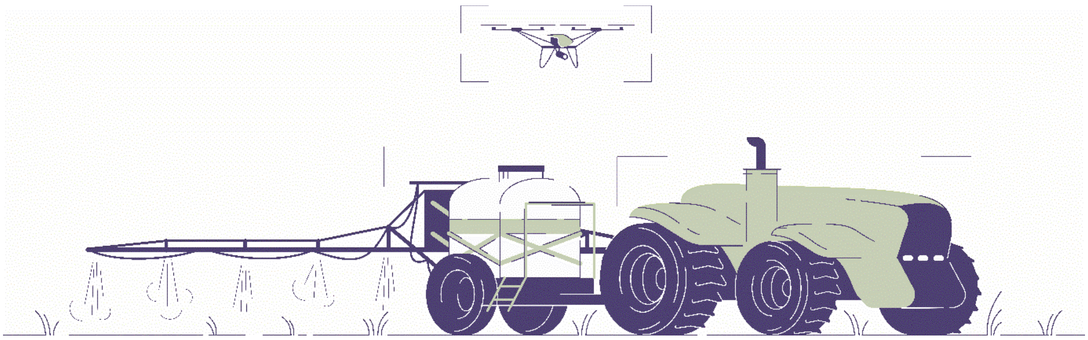
- Approximately $1,500 fuel savings per farm in the upper midwest US
- Up to 7.2% energy savings through the implementation of optimised field pathing patterns via GNNS systems.

Another system which benefits from machine guidance is controlled traffic farming. These systems involve optimised spacing of crops between permanent wheel pathing lanes, limiting compaction to these regions. Implementing this system is known to reduce fuel consumption by up to 70% and reduce run over of soil surface by over 60% when combined with GPS guidance. Reduced overlap and improved pathing efficiency reduce soil damage and compaction. Compaction can further increase costs due to increased fertilizer inputs and greater tillage requirements, with up to 30% of tractor energy being wasted via increased pulling forces required. Whilst machine guidance systems have clear benefits, improvements are proportionally higher on larger farms, particularly when factoring in significant costs related to initial purchasing.

Other precision technologies

Whilst less of an issue in temperate countries with high rainfall like the UK, irrigation is another area where precision technologies are developed. Variable-rate irrigation utilises data, and feedback sensors, to apply irrigation more precisely (via drip, trickle or micro-spraying), utilising lower pumping power, therefore, achieving water and energy savings.

Agbots, though largely still in experimental development, offer huge potentials if implemented well. These autonomous systems can monitor and map crops as well as perform precise activities such as seeding, weeding and nutrient application. Most agbots run on electricity (or hybrid power sources), therefore, reducing direct fossil fuel-related emissions, they also tend to be lighter causing less compaction related damages and could free up farm labour for other tasks. One tractor-based design demonstrated a 50% reduction in GHG emissions in weed and pest control.



Furthermore, several sensors, which alone have no direct effect on GHG emissions, can be incorporated into crop management strategies. These can improve productivity and reduce inputs, including fertilisers and chemicals. Sensors include; precision imagery (drone or satellite imagery cameras which can determine crop/soil health), soil sensors (live and historical analysis of specific farm soils) and climate sensors (weather stations provide locational, live, and historic weather data on farms) to name just a few. Geographic information systems (GIS) are also inherently utilised in almost all precision systems integrating data with spatial/geographical data for mapping.

Livestock technologies and climate mitigation

Whilst some PLF technologies are currently available on the market, this area, in general, is somewhat underdeveloped (with most focus on cattle), as such, little direct GHG emission mitigation information is available. A paper published in 2019, found that literature published lacked any PLF technology with the specific goal of reducing environmental impacts. This article, however, found a single technology involving a collar/halter/mask system for cattle which, allegedly, reduced methane global warming potential (GWP) by 85 times, though no primary literature found confirmed this. However, inferences can be made as to how certain technologies could have beneficial mitigation effects. Any technology which improves livestock health and reduces morbidity and mortality reduces CH_4 produced enterically and N_2O entering manure on a per animal basis for example.

Precision ventilation is an important area when considering indoor housing of animals as this is linked with high ammonia (NH_3) emissions. Research into automated precision ventilation found that NH_3 emissions could be reduced by 60 - 65%. Such systems also allow more accurate monitoring and benchmarking towards determining effective reduction strategies.

Precision feeding is a key methodology in improving individual animal productivity, health and reducing emissions. This utilises data from sensors such as automated weighing scales and automated feeders to optimise feed to body weight conversion, reducing inputs and reducing detrimental outputs (nitrogen in manure etc). Integration of near infra-red technologies such as NIR-4-Farm could improve tailoring of feed mixes, minimising wasted inputs further. There are also links between feed quality and rumination, towards the reduction of CH_4 emissions, with several technologies giving farmers the ability to monitor rumination 24/7 and adapt feed instantaneously.

PLF systems in dairy settings have demonstrated reductions of carbon dioxide equivalent emissions, with 69% reductions across the whole food chain demonstrated using the AfiMilk MCS milking parlour system. Automated milking systems allow the detection of mastitis early in lactation, helping farmers avoid reduced feed intake to milk conversion, which otherwise leads to increased GHG production per litre of milk. Previous studies suggested reductions of 2.5% to 5.8% (GWP) by decreasing clinical and sub-clinical mastitis cases. Equally, maintaining maximal rates of fertility in cattle has the potential to reduce GHG emissions by >20% per herd. PLF technologies look to improve reproductive efficiency via management of fertility and detecting heat in various ways. Often these technologies capture data which can link to animal health, including warnings of lameness. Cattle lameness has been shown to increase a farm's

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environmental impacts by 7 – 9%, therefore, these or bespoke lameness detection systems (3D gait analysis, floor pressure plate systems or accelerometers) would provide significant benefits. Smart bolus technologies can also play a role in detecting both disease and fertility.

Finally, drones could monitor livestock as well as crops, this could reduce fossil fuel use compared to vehicle-based observations. Interestingly, drones mounted with sensors can detect methane leaks in gas pipelines, there could be potential to adapt these technologies to assess and benchmark agricultural emissions on farms.

Barriers to adoption

PF technologies offer potential benefits, however, there are barriers present which may limit uptake. A collation of several interviews and surveys, with regards to PF technology uptake, has demonstrated that “non-adopters” noted a lack of skills and competences blocking their application of these tools usefully, along with a lack of financial resources. The key focus on improving uptake highlighted “Ease of Use” and “Usefulness” of the technologies, with farmers highly appreciative of in-field demonstrations, support services and free trials being offered. Educational initiatives have also been noted to assist in the uptake of PF tools, whilst concurrently farm size and type, as well as, specific government policies, evidence of profitability and land tenure have all been shown to positively or negatively impact their adoption.

Summary

It is clear that despite several PF reviews stating a role for these technologies in improving sustainability and reducing environmental impacts, there is, as yet, only minimal amounts of direct research available. However, inferences, and minimal direct data, all suggest positive environmental benefits, across several technologies, and also parallel economic benefits across farming systems. Whilst much more evidence of reduced inputs (associated with GHG emissions) have been observed with regards to PA, there is an increasing role for similar applications within PLF. Moving forwards more specific trials must be performed, not only on demonstrating the exact environmental impacts of these technologies but also in providing farmers with incentives for their use via evidence of potential financial gains. With the new UK agriculture bill noting the availability of financial assistance in regards to mitigating climate change and reducing environmental impacts of farming, PF technology adoption may well be more readily available for a larger variety of farmers.

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Note to editors:
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Alternatively visit www.gov.wales /farmingconnect

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